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वस्त्रादि — रंगों के अंतर में परिकलन की विधि

Indian Standard

TEXTILES — METHOD FOR CALCULATION OF COLOUR DIFFERENCE

ICS 58.080.01

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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Price Group 4

Chemical Methods of Test Sectional Committee, TX 05

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standard, after the draft finalized by the Chemical Methods of Test Sectional Committee had been approved by the Textile Division Council.

This standard is technically equivalent to ISO 105- J03 'Textiles — Tests for colour fastness Part J03 Calculation of Colour Difference' issued by the International Organization for Standardization.

The composition of the Committee responsible for the formulation of this standard is given in Annex D.

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

TEXTILES — METHOD FOR CALCULATION OF COLOUR DIFFERENCE

1 SCOPE

This standard provides a method of calculating the colour difference between two specimens of the same material, measured under the same conditions, such that the numerical value ΔE_{cmc} (1 : c) for the total colour difference quantifies the extent to which the two specimens do not match. It permits the specification of a maximum value (tolerance) which depends only on the closeness of match required for a given end-use and not on the colour involved, nor on the nature of the colour difference. The method also provides a means for establishing the ratio of difference in lightness to chroma and to hue.

NOTE — Annex A provides guidance on the interpretation of results. Annex B provides sample test data for use in checking computer programs while Annex C contains a sample computer programme for calculating colour difference.

2 PRINCIPLE

The Commission Internationale d' Eclairage, Central Bureau, Kegelgasse, Austria 1976 L^* a^* b^* (CIELAB) colour space has been modified to enhance its visual uniformity while calculating the colour difference between two specimens. The modifications to CIELAB by the CMC equation provide a numerical value, ΔE_{cmc} which describes the colour difference between a sample and a reference in a more nearly uniform colour space. This permits the use of a single-number tolerance ('acceptability tolerance' or 'pass/fail tolerance') for judging the acceptability of a colour match in which the tolerance is independent of the colour of the reference. The ellipsoid semi-axes (lS_L, cS_C and S_H) used to derive ΔE_{cmc} provide a means to interpret the three separate components of colour difference (lightness, chroma and hue) in manners suitable for a wide range of uses.

The equation for ΔE_{cmc} describes an ellipsoidal boundary (with axes in the directions of lightness, chroma and hue) centered about a reference. The agreed-upon ΔE_{cmc} acceptability tolerance describes a volume within which all specimens are acceptable matches to the reference.

The colour difference is composed of three components that comprise the differences between the reference and the specimen. These are:

a) a *lightness* component that is weighted by the lightness tolerance ($\Delta L^*/lS_L$). This is represented as ΔL_{cmc}.

   If the ΔL_{cmc} is positive, the specimen is lighter than the reference. If the ΔL_{cmc} is negative, the specimen is darker than the reference;

b) a *chroma* component that is weighted by the chroma tolerance ($\Delta C^*_{ab}/cS_c$). This is represented as ΔC_{cmc}.

   If the ΔC_{cmc} is positive, the specimen is more chromatic than the reference. If the ΔC_{cmc} is negative than the specimen is less chromatic than the reference;

c) a *hue* component that is weighted by the hue tolerance ($\Delta H^*_{ab}/S_H$). This is represented as ΔH_{cmc}.

   If the ΔH_{cmc} is positive, the hue difference of the specimen is anticlockwise from the reference in CIELAB a*, b* diagram. If the ΔH_{cmc} is negative, the hue difference of the specimen is clockwise from the reference in the CIELAB a*, b* diagram.

3 PROCEDURE

3.1 Calculation of CIELAB Values

Calculate the CIELAB L^*, a^*, b^*, c^*_{ab}, h_{ab} values for the X, Y, Z tristimulus values for both the reference and specimen as follows:

$$L^* = 116\,(Y/Y_n)^{1/3} - 16 \text{ if } Y/y_n > 0.008\,856$$

or

$$L^* = 903.3\,(Y/Y_n) \text{ if } Y/y_n \leq 0.008\,856$$

$$a^* = 500\,[\,(f(X/X_n) - f(Y/Y_n)\,]$$

$$b^* = 200\,[\,(f(Y/Y_n) - f(Z/Z_n)\,]$$

where

$$f(X/X_n) = (X/X_n)^{1/3} \text{ if } X/X_n > 0.008\,856$$

or

$$f(X/X_n) = 7.787\,(X/X_n) + 16/116 \text{ if } X/X_n \leq 0.008\,856$$

$$f(Y/Y_n) = (Y/Y_n)^{1/3} \text{ if } Y/Y_n > 0.008\,856$$

or

$$f(Y/Y_n) = 7.787\,(Y/Y_n) + 16/116 \text{ if } Y/Y_n \leq 0.008\,856$$

$f(Z/Z_n) = (Z/Z_n)^{1/3}$ if $Z/Z_n > 0.008\,856$

or

$f(Z/Z_n) = 7.787\,(Z/Z_n) + 16/116$ if $Z/Z_n \le 0.008\,856$

$C^*_{ab} = (a^{*2} + b^{*2})^{1/2}$

h_{ab} = arctan (b^*/a^*) expressed on a 0° to 360° scale with the a* positive axis being 0° and the b* positive axis at 90°.

For these equations, X_n, Y_n and Z_n are the tristimulus values of the illuminant/observer combination in which it is desired to calculate CMC ($l : c$) colour differences. The preferred illuminant/observer combination is $D_{65}/10°$. Table 1 gives the values for this and five other combinations.

Table 1 Tristimulus Values for Six Illuminant/ Observer Combinations

(*Clause* 3.1)

Illuminant/ Observer Combinations	Tristimulus Values		
	X_n	Y_n	Z_n
(1)	(2)	(3)	(4)
$D_{65}/10°$	94.811	100.00	107.304
$D_{65}/2°$	95.047	100.00	108.883
C/10°	97.285	100.00	116.145
C/2°	98.074	100.00	118.232
A/10°	111.144	100.00	35.200
A/2°	109.850	100.00	35.585

3.2 Calculation of CIELAB Colour Difference Values

Calculate the CIELAB colour difference ΔL^*, Δa^*, Δb^*, ΔC^*_{ab}, ΔE^*_{ab}, ΔH^*_{ab} using the following equations, in which the subscripts R and S refer respectively to the reference and specimen CIELAB values:

$\Delta L^* = L^*_S - L^*_R$;

$\Delta a^* = a^*_S - a^*_R$;

$\Delta b^* = b^*_S - b^*_R$;

$\Delta c^*_{ab} = c^*_{ab,S} - c^*_{ab,R}$;

$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$

$\Delta H^*_{ab} = pq[(\Delta E_{ab})^2 - (\Delta L^*)^2 - (\Delta C^*_{ab})^2]^{1/2}$

where

$p = 1$ if $m \ge 0$

or

$p = -1$ if $m < 0$

and

$q = 1$ if $|m| \le 180$

or

$q = -1$ if $|m| > 180$

where

$m = h_{ab.S} - h_{ab.R}$

In which |....| indicates that the positive value is to be used regardless if the sign of the expression between the two lines.

or the equivalent

$\Delta H^*_{ab} = t[2(C^*_{ab.S}\,C^*_{ab.R} - a^*_S\,a^*_R - b^*_S\,b^*_R]^{1/2}$

where

$t = 1$ if $a^*_S b^*_R \le a^*_R b^*_S$

or

$t = -1$ *if* $a^*_S b^*_R > a^*_R b^*_S$

3.3 Calculation of the CMC Colour Difference $\Delta E_{cmc}(l:c)$

The CMC colour difference is obtained from the following equation:

$\Delta E_{cmc}(l:c) = [(\Delta L^*/lS_L)^2 + (\Delta C^*_{ab}/cS_c)^2 + (\Delta H^*_{ab}/S_H)^2]^{1/2}$

Calculate the ellipsoid semi-axes from the L^*_R, $C^*_{ab.R}$ and the $h_{ab.R}$ of the reference as follows:

$S_L = 0.040\,975L^*_R/(1+0.017\,65L^*_R)$ if $L^*_R \ge 16$

or

$S_L = 0.511$ if $L^*_R < 16$;

$S_c = [0.0638C^*_{ab.R}/(1+0.0131C^*_{ab.R})]+0.638$

$S_H = (FT + 1 - F)\,S_c$

where

$F = \{(C^*_{ab.R})^4/[C^*_{ab.R})^4 + 1900]\}^{1/2}$

$T = 0.36 + |0.4\cos(35 + h_{ab.R})|$ if $h_{ab.R} \ge 345°$ or $h_{ab.R} \le 164°$

or

$T = 0.56 + |0.2\cos(168 + h_{ab.R})|$ if $164° < h_{ab.R} < 345°$

NOTE — The value of *l* is usually set to 2.0. The value of *c* should always remain at 1.0. This fixes the ratio of the three semi-axis to best correlate with visual assessment of typical textile samples. Other values of *l* may be required in case where the surface characteristics significantly differ from those of flat textiles.

4 REPORT OF CALCULATIONS

The report shall include the following information:

a) all details necessary for complete identification of the sample and reference specimen(s) tested;

b) identification of the spectrophotometer or colorimeter, including the CIE geometry type, with which the input data was obtained;

c) the E_{cmc} value(s) of the test specimen(s);

d) The values of l and c [for example CMC (2 : 1)];

e) The illuminant and observer conditions used in the calculations (for example $D_{65}/10°$);

f) If applicable, the acceptability tolerance used in making pass/fail judgements (*see* Annex A);

g) If required the CMC component colour difference, ΔL_{cmc} , ΔC_{cmc} and ΔH_{cmc}; and

h) If required the CIELAB L^*, a^*, b^*, c^*_{ab} and h^*_{ab} values for reference and test specimen(s) and the associated ΔL^*, Δa^*, Δb^*, Δc^*_{ab} and ΔH^*_{ab} values.

ANNEX A

(*Clause* 1)

INTERPRETATION OF RESULTS

For purposes of determining acceptability of colour match for some specific purposes, and user should determine a 'tolerance' which is agreeable to all parties involved. The ΔE_{cmc} value calculated between a specimen and a reference, when compared to this agreed-upon tolerance provides a means of determining if a specimen is an acceptable match to the reference. Specimens which are compared to the reference will fall into two chategories : those for which the ΔE_{cmc} values are less than or equal to the agreed-upon tolerance are acceptable (pass), those for which the ΔE_{cmc} values are greater than the agreed-upon tolerance are unacceptable (fail).

The equation for $\Delta E_{cmc} = 1.0$ describes an ellipsoidal boundary (with axes in the direction of lightness, chroma and hue) centred about a reference. The ellipsoid semi-axes lengths are defined by lS_L, cS_c and S_H, and when multiplied by the agreed-upon tolerance describe a volume within which all specimens are acceptable matches to the reference.

In some applications, the acceptable specimens need to be sorted into groups such that the specimens within any one group are very close colour matches to each other and could be used, for example, to manufacture a single garment. In such applications (for example rectangular '555' sorting) it becomes necessary to define subvolume of acceptability. The dimensions of each subvolume may be developed by using the ratio of the three semi-axes of the CMC volume and dividing the total acceptance volume by the number of such subvolumes. For '555' sorting this is illustrated in Fig. 1.

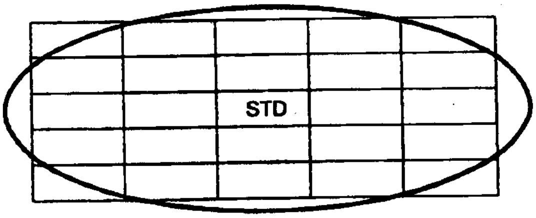

Fig. 1 555 Sort Blocks within Acceptance Volume (2-Dimenional view)

Although the total colour difference ΔE_{cmc} is valid for achromatic specimens, the method partitioning this difference is not valid when $C_{ab.R} \le 4.0$ except for lightness difference. When $C^*_{nab.R} \le 4.0$ the chroma and hue difference components often do not correspond with visual assessments. The use of the individual components for determining the size of the individual sort boxes for sorting purposes is still valid.

ANNEX B

(*Clause* 1)

REPRESENTATIVE TEST DATA

To help check computer programs giving ΔE_{cmc} values from the CMC equation, some representative test data are given in Table 2. The data are for illuminant D_{65} and the 10° observer using $X_n = 94.881$, $Y_n = 100.00$, and $Z_n = 100.00$ (from Table 1). The six reference pair colours shown are red, blue, yellow, green, grey and another red. The *l* : *c* ratio used is 2 : 1.

Table 2 Test Data for the CMC (2 : 1) Formula (D_{65}/10°)

Pair	Tristimulus values			CIELAB values			E_{cmc}
	X	*Y*	*Z*	*L**	*a**	*b**	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	69.566	70.797	67.146	87.39	5.32	7.19	
	68.614	69.698	65.942	86.85	5.59	7.29	0.42
2	53.180	57.467	66.036	80.44	– 3.35	– 3.84	
	54.385	58.760	67.111	81.16	– 3.35	– 3.52	0.45
3	63.089	67.667	23.125	85.84	– 2.45	55.67	
	61.950	66.366	22.565	85.18	– 2.28	55.52	0.27
4	23.178	28.245	21.074	60.11	– 15.44	14.97	
	21.895	27.060	20.137	59.03	– 16.64	14.86	0.97
5	12.938	13.590	16.071	43.64	0.35	– 3.39	
	12.168	12.737	15.221	42.36	0.64	– 3.65	0.81
6	14.640	11.100	11.060	39.75	27.95	2.35	
	14.520	11.190	12.220	39.89	26.57	– 0.57	2.34

ANNEX C

(*Clause* 1)

COMPUTER PROGRAM FOR CALCULATING COLOUR DIFFERENCE

This is a simple test program written in BASIC for calculating ΔE_{cmc}. Specific forms of the program may require modification for use on some computer systems.

```
10  CMC ( L : C ) COLOUR DIFFERENCE FORMULA
20  #####################################
30  'Input data and print results
40  #####################################
50  INPUT "Input CMC ( l : c ) weighting factors `1',
    `c'" ; L, C
60  INPUT "Input X, Y, Z, of reference"; X(1), X(2),
    X(3)
65  LPRINT " Input X, Y, Z, of reference " X(1), X(2),
    X(3) : GOSUB 160 : Ll = CL : A1= CA : B1= CB
70  INPUT 'Input X, Y, Z of specimen'; X(1), X(2),
    X(3)
75  LPRINT " Input X, Y, Z, of reference " X(1),  X(2),
    X(3) : GOSUB 160 : L2 = CL : A2 = CA : B2 = CB
80  GOSUB 230
90  LPRINT 'L*, a*, b*, Hue angle of reference' L1,
    A1, B1, H1
100 LPRINT 'L*, a*, b*, Hue angle of specimen' L2,
    A2, B2, H2
110 LPRINT "DL/1S1 DC/cSc DH/Sh DEcmc
    ( ' ;L;:" C" )"
120 LPRINT DL ;DC ;DH ;DE : LPRINT : GOTO 60
130 #####################################
140 'Calculate L*, a*, b* values ( d65/10 )
150 #####################################
160 X(1) = x(1)/94.811 : X(2) = X(2)/100 : X(3) = X(3)/
    107.304
170 FOR I = 1 TO 3 : IF X(I) < 8.856001E - 03 THEN
    FX(I) = 7.787*X(I) + 16/116 ELSE FX(I)
    = X(I)^(1/3)
180 NEXT
190 CL = 116*FX(2) - 16 : CA = 500*(FX(1) - FX(2))
    : CB = 200*(FX(2) - FX(3)) : RETURN
200 #####################################
210 'Calculate CMC colour different
220 #####################################
230 DL = L2- L1 ;C1 = SQR(B1*B1 + A1*A1) : C2 =
    SQR(B2*B2 + A2*A2) : DC = C2 - C1
240 Sl = DL*DL + (A2 - A1)*(A2 - A1) + (B2 - Bl)*
    (B2 - B1)
250 DH = 0 : AA = S1 - DL*DL* - DC*DC ;IF AA<
    = 0 THAN 260 ELSE DH = SQR(AA)
260 IF (A2*B2) = 0 THEN 280 ELSE H2 = 180 -
    SGN(B2)*90 - ATN(A2/B2)*57.3
270 GOTO 300
280 BB2 = SGN(ABS(B2)) : AA2 = SGN(A2 + B2)
290 H2 = 90*(BB2 - AA2 + 1)
300 IF (A1*B1) = 0 THEN 320 ELSE  H1 = 180 -
    SGN(B1)*90 - ATN(A1/B1)*57.3
310 GOTO 340
320 BB1 = SGN(ABS(B1)) : AA1 = SGN(A1 + B1)
330 H1 = 90*(BB1 - AA1 + 1)
340 IF H1<= 164 OR H1>= 345 THEN 350 ELSE GOTO
    360
350 T = .36 + ABS(.4*COS((H1+35)/57.3)) : GOTO 370
360 T = .56 + ABS(.2*COS((H1 + 168)/57.3))
370 SL = .040975*L1/(1+.01765*L1) : IF L1<= 16 THEN
    LET SL = .511
380 SC = .0638*C1/(1 + 0.0131*C1) + .638 : F = SQR(C1^
    4/(C1^4 + 1900)) : SH = SC* (T*F + 1 - F) : DL =
    DL/(L*SL) : DC = DC/(C*SC) : DH = DH/SH
385 DA = H2 - H1 : IF ABS(DA)>180 THEN Y1 = - 1
    ELSE Y1 = 1 : Y2 = Y2 = Y1*DA
386 Y2 = Y1*DA : IF Y2<= 0 THEN DH = - DH
390 DE = SQR(DL*DL + DC*DC + DH*DH)
400 RETURN
```

ANNEX D

(*Foreword*)

COMMITTEE COMPOSITION

Chemical Methods of Test Sectional Committee, TX 05

Organization	*Representative(s)*
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(*Continued on page 7*)

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